Declass Review by NGA.

[redacted]

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TECHNICAL PROPOSAL
for a
RAPID ALIGNMENT DEVICE
for
MICROSTEREOSCOPE

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FOREWORD

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The following is submitted by the [redacted] in response to a Request for Proposal for a Rapid Alignment Device for Microstereoscopes.

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1.0 INTRODUCTION

For sometime, Microstereoscopes have been in general use by the photo interpreter which allow detailed viewing of stereo imagery at relatively high magnification. More recently, these instruments have been complemented by attachments which permit partial rectification of either or both input photographs in order to permit stereo viewing of image pairs which are not inherently aligned, e.g., with different perspective. These attachments use variable anamorphic magnification to match the geometry of unequal pairs of photographs so that the image may be fused by the operator's eyes. Experience with these anamorphic devices has shown that, in practice, the alignment procedure required to obtain stereoscopic fusion, is difficult and causes considerable eyestrain to the operator when the disparity of the two images is excessive.

In the following, two devices are described which alleviate this problem by superimposing both images from the left and right section of the stereoscope. One configuration of the rapid alignment device (RAD) terminates in one eyepiece (monocular RAD), while the second version permits binocular viewing of the superimposed imagery. By means of this device, the operator may view the image without eyestrain until complete match is achieved. After quick removal of the RAD, perfect fusion of the imagery is then possible.

2.0 BASIC CONFIGURATION

The requirement of superimposing the image from both sections of a stereoscope implies the removal of the regular eyepieces and relaying the final aerial image plane of the stereoscope to a new position. Along this optical path, a half silvered mirror (beamsplitter) at an equal optical distance from the left as well as the right image plane, combines the imagery in two directions. One optical path contains the reflected image from one channel and, superimposed, the transmitted image from the second channel. The second path combines the transmitted image of the first channel with the reflected image of the second channel. Only one of these optical paths is used in the monocular version, while both paths are utilized in the binocular device. The relayed image in both cases is then observed through regular eyepieces.

The proposed rapid alignment device is very simple and straightforward and poses a mechanical configuration problem rather than
But the optics are not commercially available - See Pg. 3-3
one of optics. This mechanical complexity is because of the necessary accommodation to various interpupillary distances, tilted and parallel eyepiece tubes on the microstereoscope, and the requirement that the images remain erect and non-rotated. In addition, there are the practical considerations of weight and size.

2.1 Monocular Device (MonoRAD)

The technical solution which is proposed for the MonoRAD is shown in Fig. 1 and 2. Fig. 1 is the external configuration of a monocular RAD. It consists of two sections which rotate

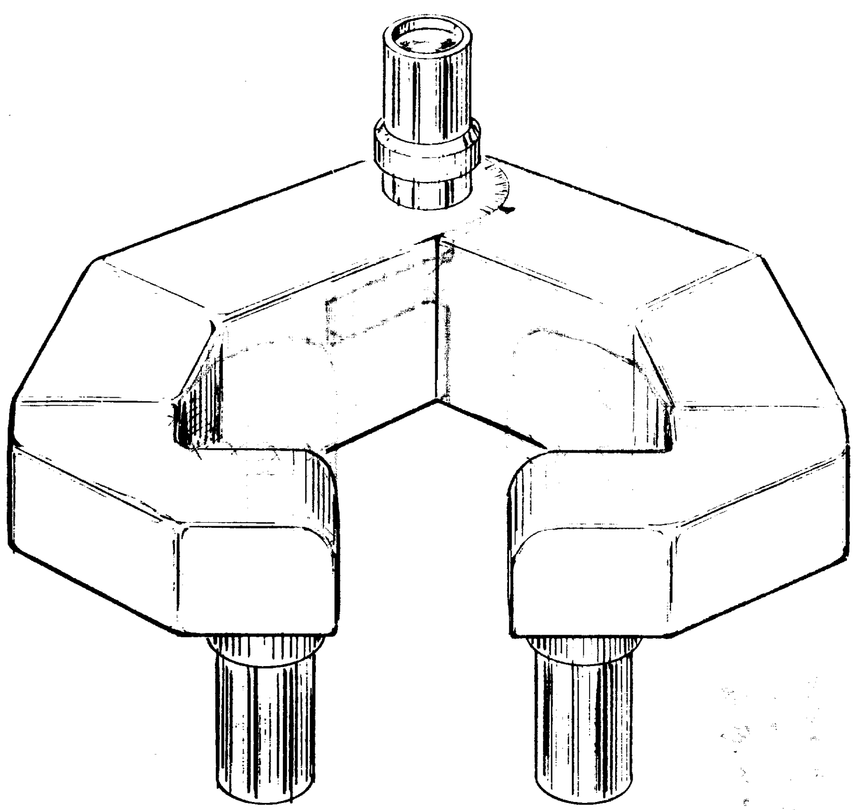

Figure 1   MonoRAD, External Configuration

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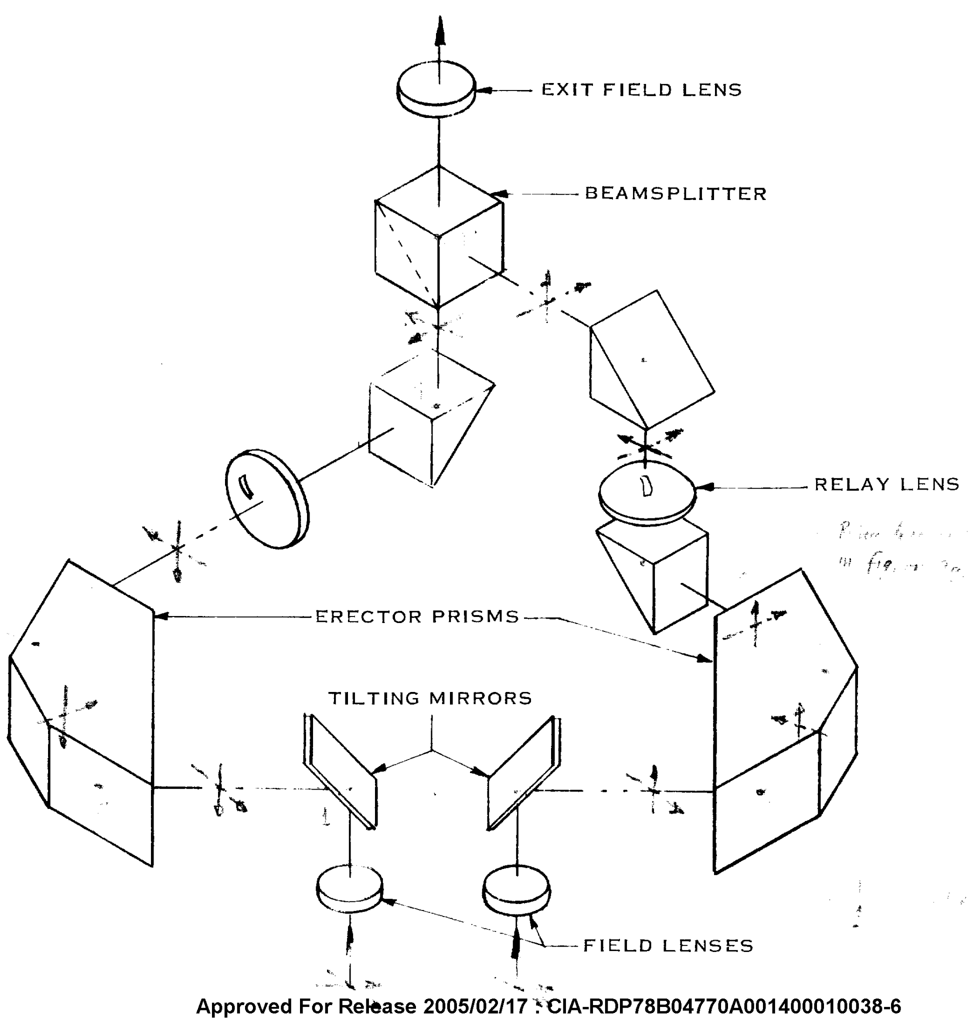

Figure 2 MonoRAD, Schematic Optical Diagram

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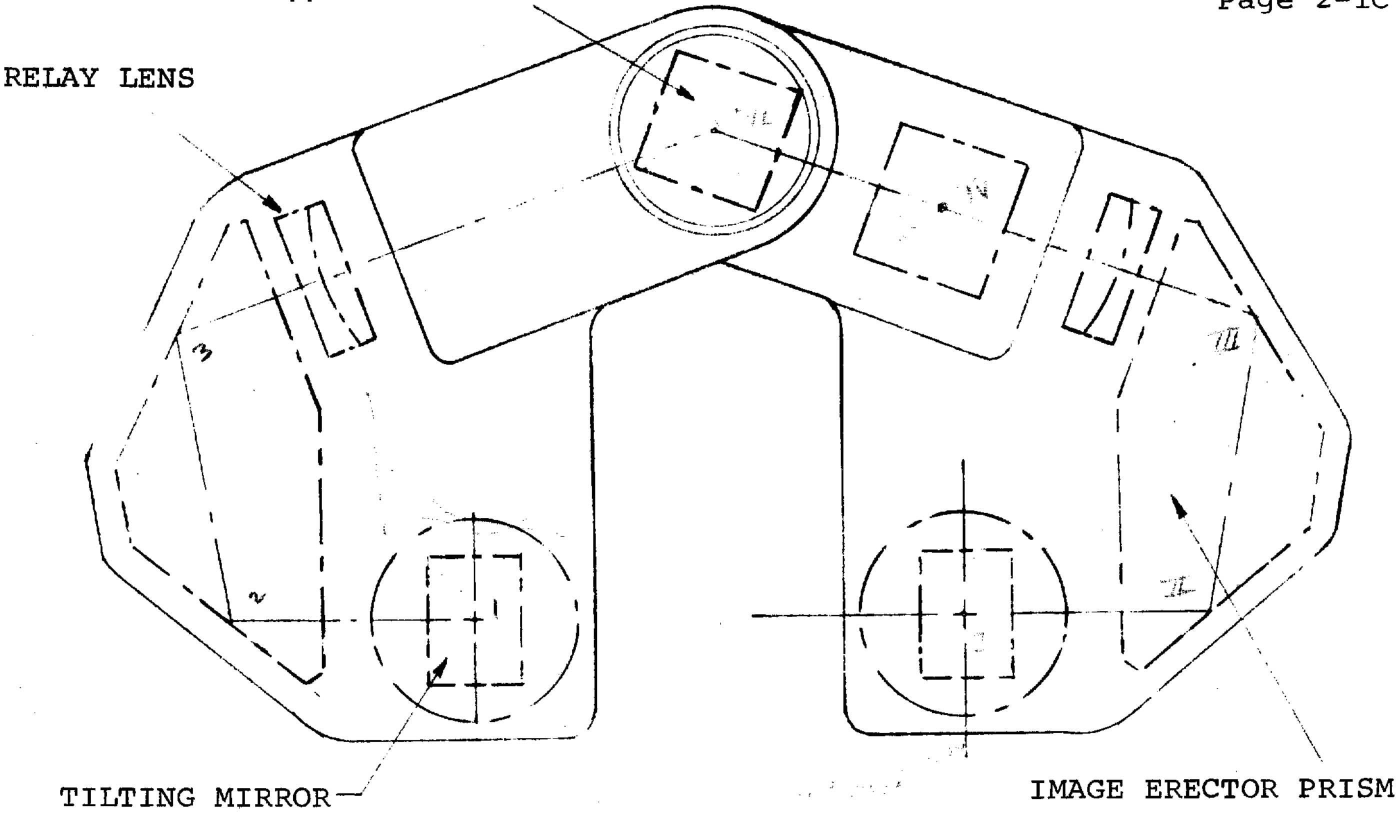
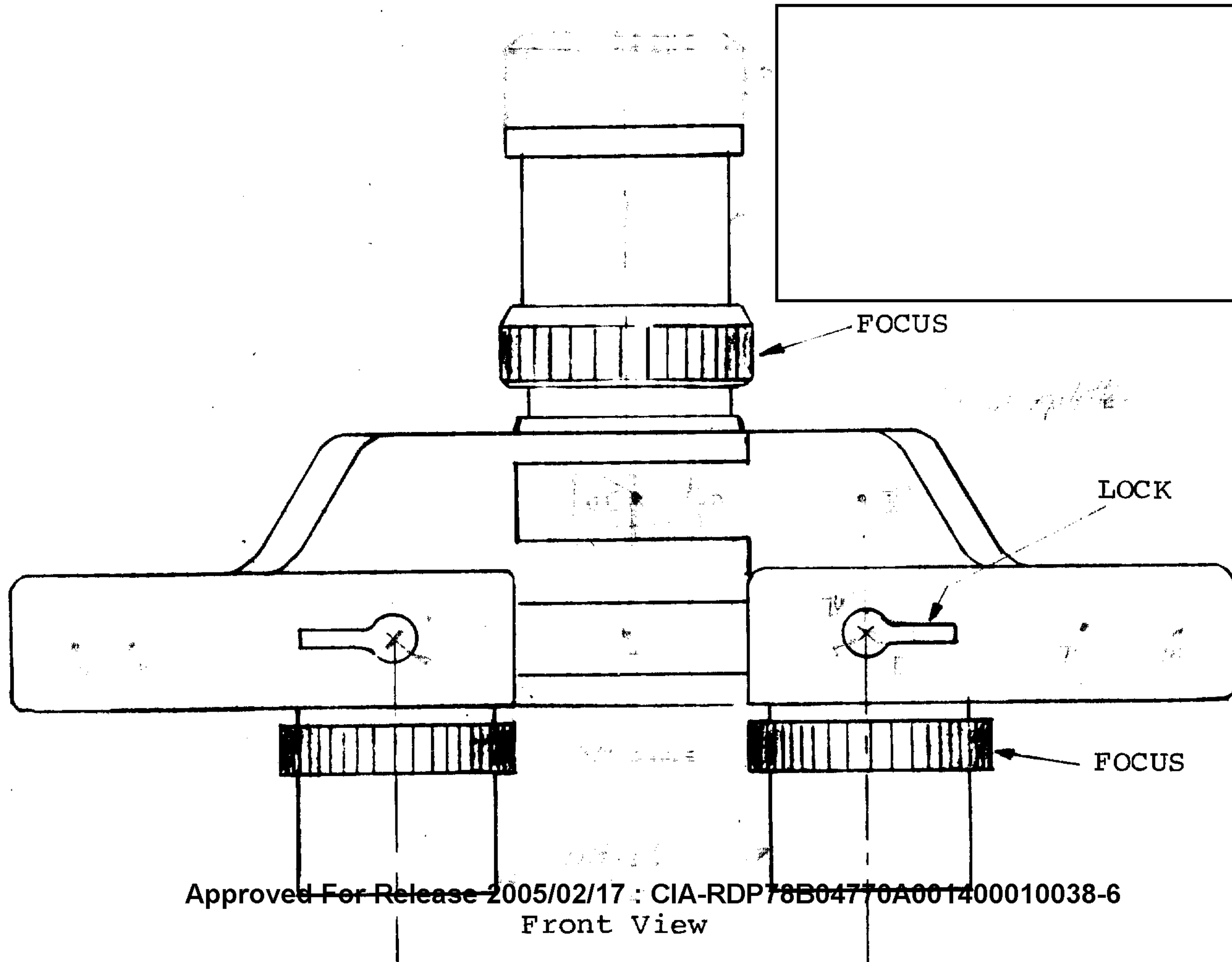


MonoRAD - Top View



Front View

about the optical axis of the exit eyepiece tube to accommodate interpupillary adjustment. This method of adjustment is borrowed from a design used successfully on some binocular microscopes. The two protruding input sections contain image erecting prisms and tiltable adapters, which are inserted into the eyepiece tubes of the microstereoscope (or the anamorphic adapters) in place of the regular eyepieces.

Figure 2 is an isometric optical diagram (not to scale) which shows the optical configuration. To relay, erect, and superimpose the two images, four reflections are necessary for the left channel and six reflections (including one on the beamsplitter) for the right channel. Since four reflections are the theoretical minimum for a prism erector system, the total light loss in the proposed instrument will be minimized.

Following the left channel optical path from below, the light passes through a field lens and is reflected on a first surface mirror outwards (to the left). The eyepiece adapter tubes (in which the field lens is located) are tiltable about a horizontal axis at the mirror surface to accommodate their insertion into stereomicroscopes with inclined eyepiece tubes Stereozoom 70). A mechanism rotates the mirror through half the tilt angle of the input tubes so that the optical axis is always reflected into a direction perpendicular to the entrance face of the following image erector prism. In this prism, the optical path is reflected about 110 degrees on each of the two surfaces. Following this, the light passes through the relay lens which is located exactly at the optical center between input image plane and exit image plane for unity magnification, and is further reflected 90° up into the eyepiece tube. Passing through a beam splitter tube, and another field lens, the final image is then formed at the back focal plane position of the eyepiece. 25X1

because one side reflected more than
the other it will be dimmer
more hard to see

Anamorphics 4" long
4+3 = 7" above the eyepoint
of Zoom 70 means operator
must stand to effect alignment

but

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The optical path for the right channel is similar and equivalent except that the relay lens is located physically in a different position. In order to maintain equal optical path in glass on both sides, the additional reflection (II) between image erector prism and relay lens in the right channel, will be either on a mirror surface, or, if a prism is used, an equivalent block of glass must be cemented onto the image erector prism of the left channel. The images of both channels are combined on the beam splitter which is mounted in the right-hand assembly and moves with it. Only half of the combined image is used; the reflected image of the left channel and the transmitted image of the right channel is not needed and is absorbed within the housing.

The mechanical configuration of the MonoRAD is such that the eyepoint of the new eyepiece is located about 3 inches above and about 2.5 - 3 inches behind the position of the eyepoint of the original instrument. This places the center of gravity over the instrument so that there is no danger of the microstereoscope tipping due to the added weight of the RAD.

It should be pointed out that the input eyepiece tubes tilt in a vertical plane with their axes of rotation being parallel only if the interpupillary distance is adjusted to 65 mm (mid-range). If the instrument is set to other distances, the axes of the input tubes are still coplanar, but with different inclination. The effect is that the output eyepiece tube will tilt slightly from the original direction, as interpupillary adjustments are changed. This, of course, applies only to stereoscopes with inclined eyepieces. On the High Power Stereoviewer, with parallel eyepiece tubes, the monocular viewing tube will be colinear with the original direction.

Image will rotate with change in IPD ?

Insertion and removal of tiltable adapters into non-parallel eyepiece tubes will necessarily cause change in IPD of tubes.

2.2 Binocular Device (BinoRAD)

The binocular RAD is shown schematically in Figures 3 and 4. Figure 3 shows the external configuration. The two major assemblies interlace and rotate with respect to each other about a vertical axis. This, in turn, moves the four eyepiece tubes in an arc for interpupillary distance adjustment. The use of the device on microstereoscopes with inclined eyepiece tubes is made possible by rotating the input tubes about an axis which is colinear with the optical axis in the instrument after the first 90° reflection. This method is convenient and is used in some periscopes to scan objects in various directions, but causes the optical image to rotate. In order to derotate the image, the exit eyepiece tubes will be mechanically connected to the input tubes and will tilt through the same angle. (on one side of the instrument) Therefore, since the exit and entrance axis of the instrument are parallel, the final image will not be rotated. (but the axes of the right entrance and left exit will not be parallel)

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The optical configuration of the device is shown schematically in Figure 4. The image combining beam splitter is again located at the same optical distance from both input image planes and in addition is symmetrical about input image and output image planes. The optical path is reflected through a series of prisms which erect the image and avoid physical interference of the two assemblies. The number of reflections necessary to do this is eight for the left channel and ten for the right channel. The optical path length and, of course, the total weight of the device is increased compared to the monocular version. However, by observing the basic considerations on aperture sizes and path lengths discussed in Section 3.1, the overall size of the BinoRAD is hardly larger than that of the monocular version.

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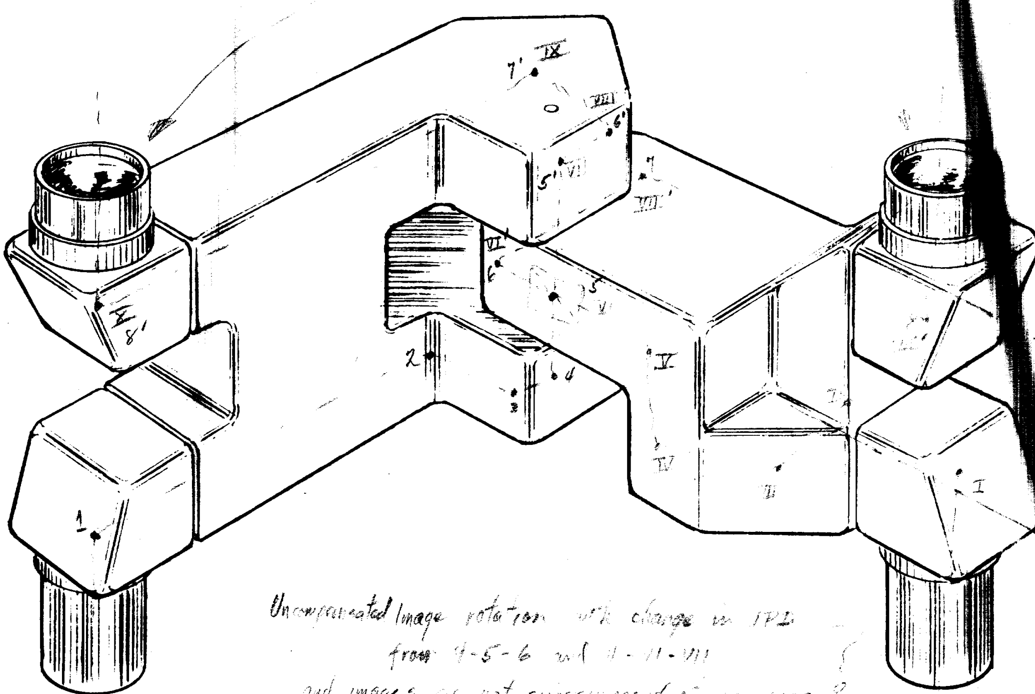
Eyepieces at [illegible]



Uncompensated Image rotation with change in IPD
from 4-5-6 and I-II-VII
and images are not superimposed at eyepiece ?
or is it compensated by the change of 1 & I

Figure 3 BinoRAD, External Configuration

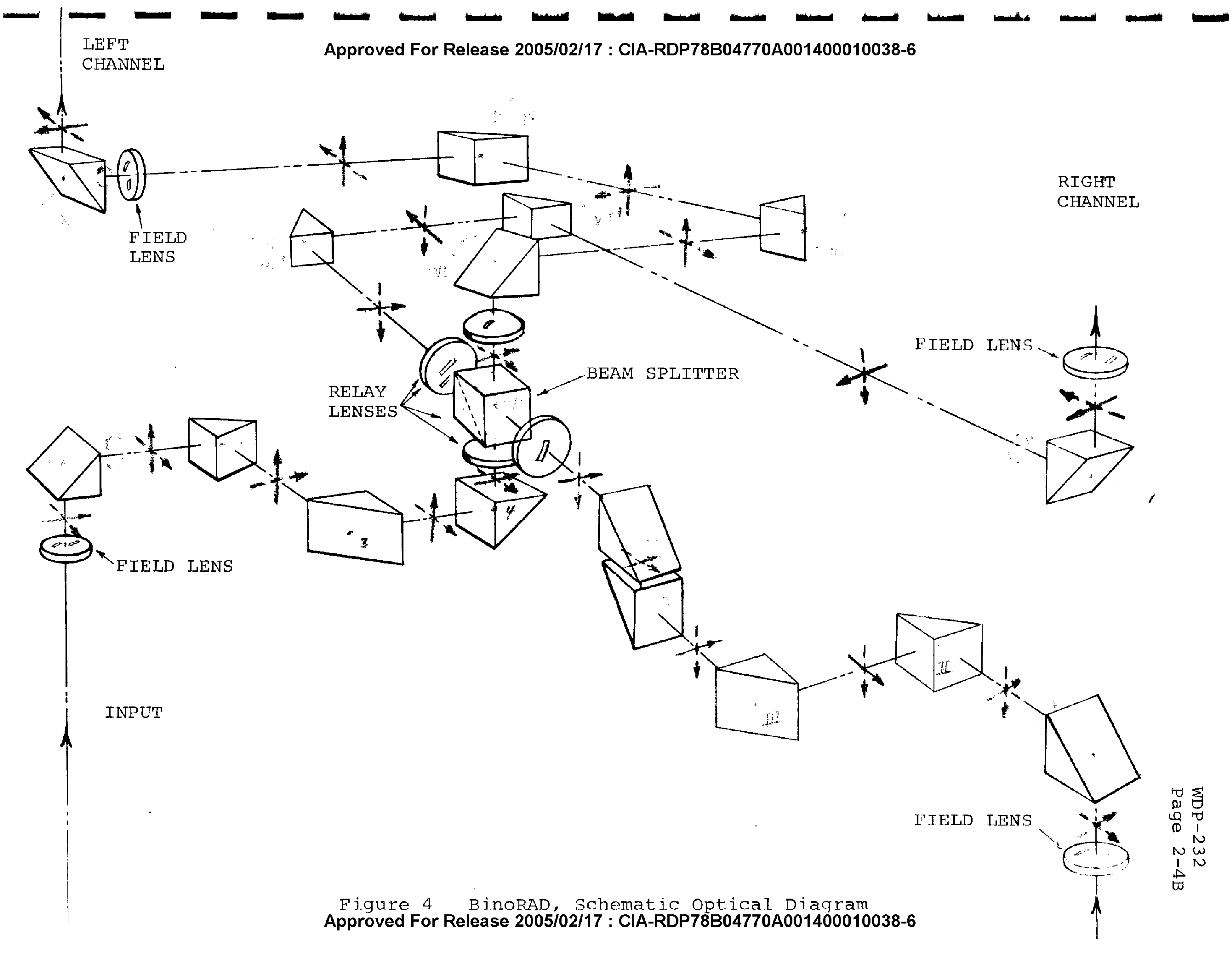


Figure 4 BinoRAD, Schematic Optical Diagram

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The eyepieces themselves tilt about axes which are never parallel. Therefore, if the instrument is used on stereomicroscopes with inclined eyepieces, the main body of the BinoRAD will be tilted with respect to the image plane. The tilt will be towards the horizontal which will improve the appearance of the combined microstereoscope -- anamorphic adapter-- rapid alignment device.

The number of reflections between the input field lens and relay lens, and between relay lens and output field lens is different in the left and the right channel. Therefore, one reflection in each path of the right-hand assembly should be on a first surface mirror, or compensation for the additional glass must be provided in the left channel. Because of weight considerations, it may be necessary to utilize mirror systems rather than prisms in the BinoRAD, even at the expense of lower light efficiency. A careful size and weight analysis will be performed in order to arrive at the best solution.

Optical considerations which apply to the MonoRAD as well as to the BinoRAD are discussed in the next section. A tentative list of optical elements needed for the devices is included in the Appendix.

3.0 OPTICAL CONSIDERATION

3.1 PATH LENGTH AND APERTURES

Practical considerations of size and weight, commensurate with this type of equipment, dictates that the total optical path through the instrument be kept as short as possible. These considerations have led to the configuration of the monocular and binocular version as previously described. The optical path length at each bend in the optical path is dependent upon the aperture for the imaging bundle at that position. For this reason, all prisms in the instrument will be dimensioned to be no larger than that required at that particular position. The entrance and exit aperture must be large enough, however, to pass the full field (approximately 20 mm) of the original instrument. This determines not only the minimum size for all prisms, but also the clear apertures and focal lengths for field and relay lenses.

The necessary bends in the optical path may be accomplished by reflections on first surface mirrors or by total reflection in glass prisms (as shown in Figure 2 and 4). The use of glass prisms has the advantage that the optical path becomes shorter than the physical distance between elements which permits smaller apertures for the relay lenses, and smaller dimensions for some prisms. Another advantage is that assembly of the instrument is simplified since part of the alignment accuracy is inherent in the prism angles, particularly when compact pre-cemented prism assemblies with more than one reflecting surface are used. Light losses in totally reflecting prisms are also less than the light losses on first surface mirrors. The primary argument against exclusive use of prisms is their weight, which, in this particular application, is an important consideration.

3.2 PUPILS AND EYE RELIEF

It is a requisite that not only the image at unity magnification must be relayed to the final position in the exit eyepiece tubes, but that the pupils of the original microstereoscopes must be relayed correctly, as well. Microscope eyepieces are designed for a 240 mm tube length, which is standard in modern instruments. The exit pupil of the eyepiece, which is actually the real image of the objective pupil, is located at a specific distance from the eyepiece. This distance is called the eyerelief. It is important to optically design the RAD such that the eyerelief is maintained. This is achieved by the combination of two field lenses. The first field lens forms an image of the instrument pupil at the location of the relay lenses. The second field lens creates a virtual image of this pupil at the correct optical distance of 240 mm from the exit tube. In order to avoid light losses, and to maintain the numerical aperture of the microscope, this dimensioning of pupils must be done for the lowest magnification of the primary stereomicroscope.

3.3 FOCUS

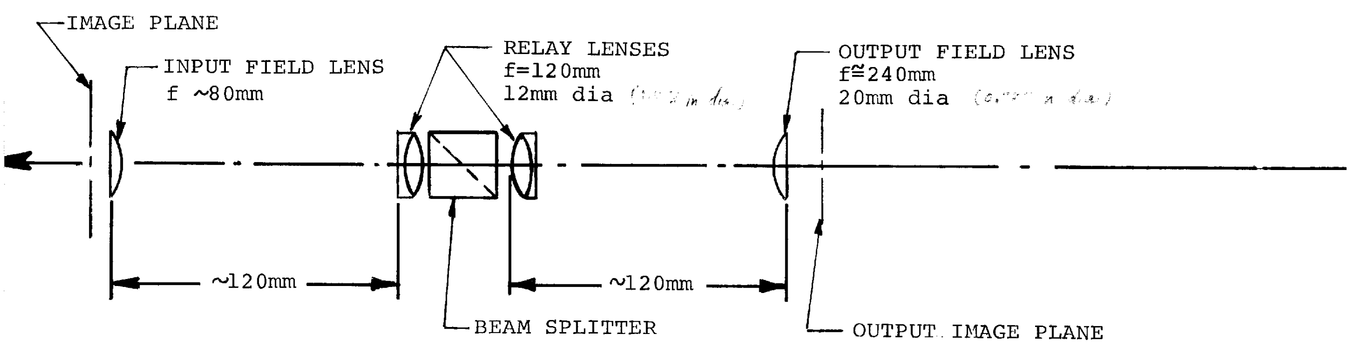
In order to compensate for differences in refractive power of the operator's eyes, binocular microscopes have one focusable eyepiece. Binocular zoom microscopes, on the other hand, have both eyepieces (actually the eyepiece tubes) focusable since the image planes must remain in a fixed position in order to maintain the parfocal property throughout the zoom range. Because of the possible differences in the operator's eyes, the eyepiece tubes on which the RAD is to be mounted, may be at unequal height. Therefore, at least one of the input tubes of the RAD, which replace the regular microscope eyepieces, must be focusable in order to compensate for this condition. Unfortunately, the relative position of the parfocal image plane inside the eyepiece tubes, is not identical for all microstereoscopes. This is dependent upon the location of the back focal plane of the eyepiece, which varies with the particular optical and mechanical design of eyepieces. It is, therefore, suggested that both input tubes for the RAD should be focusable.

Since the internal dimensions of the RAD will not change, the relay lenses need not be focusable. The image plane will then be relayed to a fixed, standard position within the output eyepiece tubes. One of these tubes must also be focusable, however, in order to accommodate differences in the operator's eyepower. On the monocular version, the single eyepiece tube must be focusable.

3.4 OPTICAL DESIGN

Figure 5 shows a simplified, straight line optical schematic of the RAD, ignoring the glass prisms in the optical path. In the optical design of the instrument, it will be assumed that the input image is perfectly flat and aberration free. Input and output field lens will be outside the respective image planes so that any dust on their surfaces will be out of focus. As mentioned before, not only will the image be relayed at unity magnification, but the pupils must be relayed correctly as well. Since these conditions are unique to this particular instrument, commercially available optics cannot be used. The optical design, however, is relatively

BINOCULAR VERSION



MONOCULAR VERSION

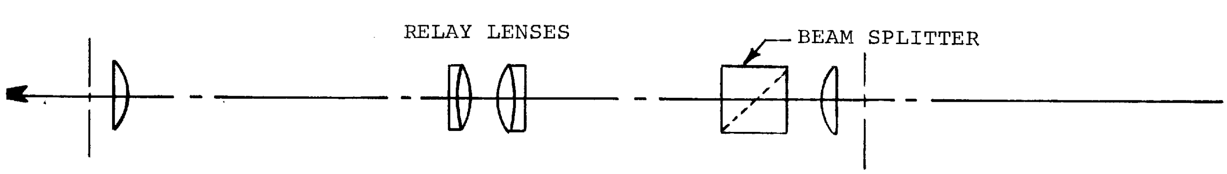


Figure 5 Simplified Optical Schematic

simple. Since the system is almost symmetrical, the field lenses can be plano convex single elements. The relay lens consists of two achromatic doublets or one (Hastings) triplet. In the case of the binocular version, two doublets will be used with the beam splitter in collimated light. The optical design, as well as the performance analysis, will be done with an available automatic lens design program ACCOS) designed for the [redacted] IBM 360 Computer.
The lenses and prisms will be made by one of several qualified vendors which specialize in the fabrication of precise optical elements to specification.

In order to preserve contrast in the relayed image, design practices commensurate with this type of equipment will be rigorously observed. For example, all non-reflecting and non-transmitting surfaces on prisms will be ground and inked black and all tubing, etc., is oversize and black anodized to avoid glare. Baffles or aperture stops will limit the light bundle passing through the instrument to only the required aperture in accordance with general practices of high quality instrument construction.

4.0 MECHANICAL DESIGN

Both binocular and monocular optic assemblies would be housed in 356 aluminum alloy castings to attain maximum rigidity with minimal weight and the fewest number of machined components. A quick disconnect to interface with the anamorphic lenses utilizing the split barrel technique, would provide maximum bearing area and least deflection. Focus adjustments would be made by conventional microscope mechanism.

Both configurations are free to rotate about a bearing along the vertical axis of the beam splitter, to give the required operator interpupillary distance. Rotational resistance is built into this bearing using wave springs and friction material washers for correct operator "feel".

Focusing adjustment where required is made by rotating knurled rings which translate the appropriate lenses, via fine screw threads.

Adapter removal via a quick disconnect is implemented by depressing a lever which unclamps a split barrel that fits on to the anamorphic eyepiece.

The castings and all mechanical components will be black anodized or painted optical black. The weight of the monocular adapter will be approximately 5 lbs. and the weight of the binocular adapter will be 7 lbs.

4.1 INTERPUPILLARY INTERFACE COMPENSATION

In order to compensate for interpupillary adjustments at the adapted interface, it is necessary to incorporate a self-adjusting mechanism to obtain the correct optical reflective angle at the first mirror after the interface.

4.1.1 Monocular Configuration

spherical bearings permit rotation about more than one axis – see pp. 2-2 and 2-1C

The adapter barrels terminate in spherical bearings which are self-aligning along the axis of the anamorphic lenses. The spherical bearings are entrapped within the adapter housing and must be permitted to rotate only around one axis and are self-cleaning through a wiper action. dirt shouldn't get this far As the spherical bearing rotates, it turns an integral spur gear that drives a mirror via a two-to-one gear reduction; thus maintaining the correct reflective angle, irrespective of the anamorphic interpupillary distance. Refer to Figure 6. where is Fig. 6

4.1.2 Binocular Configuration

The adapter barrels for the BinoRAD are free to rotate about one axis to compensate for interpupillary adjustment at the interface. In this case, however, image rotation is prevented by rotation of the eyepieces through a similar angle. A simple arrangement utilizing two similar spur gears and an idler gear suffices for this compensation.

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LIST OF OPTICAL PARTS (MonoRAD)

Number Required	Description
2	Input field lenses, plano convex, f ≅ 120 mm, dia 22 mm, CA 20 mm
2	Relay lenses, Achromatic triplet, f ≅ 60 mm, CA 12 mm
1	Output field lens, plano convex, f = 240 mm, dia 22 mm, CA 20 mm
2	Input mirrors, 20 x 30 CA x 3 mm
2	Prisms, (220° deviation by two reflections), entrance faces 18 mm
2	90° prisms, faces 18 mm
1	Mirror, 15 x 22 CA x 3 mm
1	Beam splitter cube, at least 40% reflection, 40% transmission, 3 outside surfaces polished, 20 mm cube

LIST OF OPTICAL PARTS (BinoRAD)

Number Required	Description
4	90° prisms, 20 mm faces
2	Periscope (90-90) prisms, 20 mm faces
2	Periscope (90-90) prisms, 16 mm faces
2	90° prisms, 15 mm faces
2	U-bend prisms, 15 mm faces
1	Beam splitter cube, 14 mm, 4 outside faces polished
2	Input field lenses
2	Output field lenses
4	Relay lenses, achromatic doublets, 14 mm CA